USER-CENTRED DEVELOPMENT OF AN USER INTERFACE
FOR MOBILE DEVICES IN AUTOMATION

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Abstract: Mobile devices become more and more powerful. But the advantages of such devices can only be used if the interface between the user and the technical functions is designed well. This paper describes the iterative and user-centered user interface development process for such a user interface for two different user groups (technician and manager) in the domain of service and maintenance in industrial automation. At the end of the iterations a usability test showed that a user interface on the basis of this concept is a useful support for the service- and maintenance personnel during their daily work.

Keywords: User interface, requirement analysis, mobile devices, service and maintenance, user-centred development.

1. INTRODUCTION

Nowadays the trend in the production industry is to centralize modern production systems. E.g. almost autonomous power and heating plants will be spread over the cities and regions. Supervisory control of these highly automated plants is still necessary and is performed in a central control room (Fig. 1; Wittenberg, 2003). Although these plants are autonomous there is still a need for service & maintenance activities. For safety reasons critical process values have to be controlled onsite regularly (e.g. every 24h or 36h) by law. In case of malfunctions the service and maintenance staff has to react very fast and correct to reduce downtimes and costs, and to increase the safety.

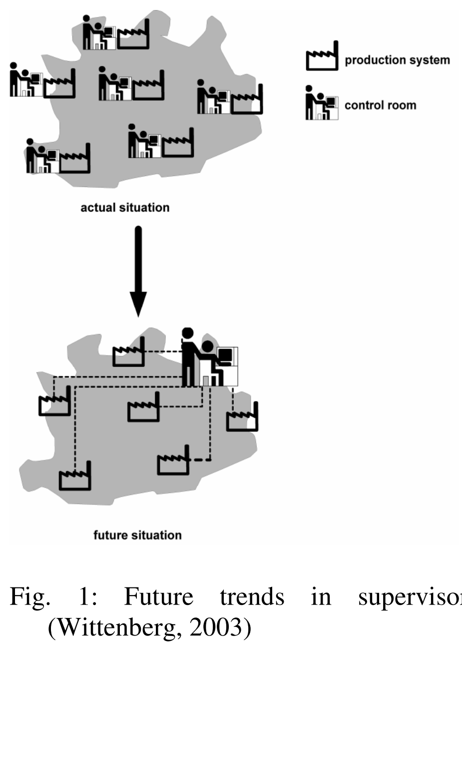

Fig. 1: Future trends in supervisory control (Wittenberg, 2003)

2. MOBILE DEVICES FOR INDUSTRIAL USE

Actual panel computers ("web pads") usually have a high-resolution 8" or larger colour display which allows the sharp display of pictures, even under adverse lighting conditions, and are able to access through a wireless network an information server. Modern wireless network protocols like 3G ensure the necessary data transfer rate. The battery modules become more and more powerful so that these panel computers can be operated alone for a full working shift. The working staff can access every needed information and data at every location – even under the roughest industrial environments. This development will change the working situation of the staff. The challenge is to develop a user-centered mobile human-computer interface concept – beginning with a requirement analysis over the concept development to the evaluation by usability tests.

3. USER-CENTRED DEVELOPMENT

The development process of user centred user interfaces (compare ISO 13408) describes the procedure of the development of suitable interfaces between humans as users and technical systems. In the early system development phases the future users' requirements can already be collected via analyses of the tasks on site or via expert inter-views. In this phase mainly the user context (ISO 9241-11), that means the user, his tasks, his work equipment and his physical and psychical environment is got known and understood. Furthermore the user and task requirements get determined (compare ISO 13407).

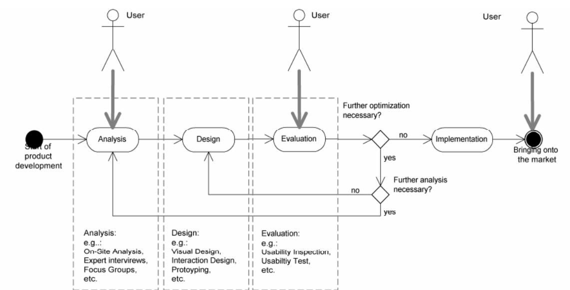

Figure 2: User Centred User Interface Development Process

In subsequent phases of the user interface development the users give important hints within the evaluation of prototypes with different functional characteristics up to products which are already ready for marketing, for example in usability tests (Mandel, 1997; Nielson, 1993).

With complex products usually diverse iterations are necessary in order to get a user interface that supports the user optimally in fulfilling his task (DIN EN ISO 13407). Figure 2 outlines the user centred development process.

Following the user centred development process products have according to DIN EN ISO 13407 the following properties:

- The products are easier to understand and to use what reduces training and extra expenses.
- They increase the user satisfaction and decrease discomfort and stress.
- They improve the user's productivity and the organizations' efficiency.
- The product's quality is improved and can lead to a competitive advantage.

The present research project focuses on the first part of the user centred development process, the analysis of the use context (use context analysis, see section 3) and of the user requirements (user requirement analysis, see section 3). In order to verify the results of the analyses a prototypical implementation was developed (design phase) and evaluated in usability tests (evaluation phase).

4. FIRST ITERATION

Within this presented research project two intensive use context and requirement analysis in different domains (Power Generation and Chemical Industry) were performed. The two user groups (technician and manager) in the field of service and maintenance were analysed.

3.1 Requirement analysis

The first requirement and use context analysis focused the service and maintenance technicians – the staff who is working direct at the productions process. Two onsite analysis and a number of expert interviews with service and maintenance staff were conducted in 2002. As a result of this analysis the hierarchical task structure for typical tasks and generic tasks were identified. As a huge optimization potential the integration of different information sources like plant documentation, history information and the task schedule into one human-computer interface was identified. Also the acceptance of future technologies like speech in- and output were queried.

Typical task scenarios were recorded. E.g. a common scenario is the calibration of instruments or drives. The calibration of drives for valves is performed regularly. The process visualization in the control room shows an impossible process value for a valve (e.g. 112% open, a value larger than 100% is impossible). The operator informs the maintenance staff to calibrate this drive. The maintenance technician has to walk to the valve and begins the calibration. Due to the missing onsite presentation of the process value of the valve the maintenance staff has to communicate with the operator in the control room to get a feedback about the calibration action. This communication can be very inaudible because of the production noise. In case of a malfunction of an element of the production process (e.g. a pump) the maintenance staff has to react very fast to keep the safety and reduce downtimes. For a correct diagnosis the staff needs information about the history of the element (message lists), the right documentation (nowadays printed on paper), and ideally a repair instruction. Often spare parts ore special tools are needed which have to be ordered from a different department. The following list shows some of the important problems as perceived by the maintenance personnel (Wittenberg, 2003):

- Need to move a long distance to communicate with their colleagues
- Loud noise hampering communication, inability to access help while working in a remote places and difficult positions.
- Inability to order for spare parts easily and a lot of time wasted to collect the spare parts.
- Time lag between initiation of communication and reciprocation.
- Complex procedure of communication to request for process stopping and resumption with control room.
- Redundant paper work for administrative purposes, especially writing reports.

As another result of the analysis the following optimization potentials were identified (Wittenberg & Otto; 2003a & b):

- Information acquisition: The pick-up of information by the service and maintenance staff is not suitable for the task. Nowadays the complete plant documentation is stored as paper printout in a special documentation room. It is not allowed to take (even parts of) the documentation out of this room. As a consequence the service and maintenance staff has to make copies of the documentation or to describe by hand the needed data, to identify the corrective measures onsite by the process element. If the information which is token along insufficient or wrong, the service and maintenance staff have to begin again with the information acquisition.
- Communication between Service- and maintenance staff and operator: The service and maintenance staff frequently needs process information, which is only displayed in the central control room. Via walkie-talkie or mobile phones the service and maintenance staff has to ask this information from the operator in the control room. A problem is the high noise level in production plants which disturbs the communication.
- Different data format: A lot of different data formats and materials (paper, electronically) were found. Starting with a mission list over the plant documentation to the spare parts list for each process element. A unification of the different data formats is desired.
- Supply of situation-depended interactions and information: A support of the workflow is required. The service and maintenance staff should get offered situation-depended functions and information, e.g. information for diagnosis or a direct access to the spare part ordering.

The recorded workflow is presented in (Wittenberg 2003; 2004).

3.2 User Interface concept development and evaluation

Based on the first requirement analysis a first user interface concept and a prototype for two scenarios (a calibration scenario and a repair of a pump scenario) were developed. The prototype was developed in Macromedia Flash® so that it runs on almost every mobile device in the frame of a web-browser with a Macromedia Flash®-Plug-in. This prototype comprises a task-card concept for the fulfilment of the typical workflow recorded in the requirement analysis. This task-card concept covers the whole range from the incoming order over the element history and documentation to the spare part ordering. The user interface concept and the prototype are described in (Penzkofer, 2002; Wittenberg & Otto; 2003a & 2003b).

As an evaluation a usability test with two different user groups was performed. The test subjects were carefully selected so that the test sample could include maintenance personnel who were novices and experts. The results of the usability testing are described below. The participants were chosen in such a way that they came from work places which differed in the extent of automation. The number of participants was seven with an average age of 23 years and between ages of 22 and 45 years with educational background in electrical and mechanical engineering and the participants experience varied from being an apprentice to 28 years. Two scenarios were used for usability testing of the prototype. These were the common and everyday tasks the maintenance personnel performed. One of the scenarios was part of the mechanical maintenance and the other was electrical maintenance.

1. Pump Repair: The scenario was to repair a pump which has gone out of order, the task was to identify

the problem seek online help/documentation, order spare parts (here in this case order for a set of screws) and finally write a report about the repair (if it was repaired or the status of the repair to inform the supervisor.

2. Calibration of Actuator for a valve: This scenario was to identify where the problem lies, seek online help to dismantle the actuator, calibrate the actuator, send a message to the control room to reactivate the process (which has been deactivated for maintenance) and write a report.

As a result of the evaluation the acceptance of mobile computers and a widespread interface is high. The subjects mentioned consistently that such a concept would support their daily work. The inquiry of the five Usability Dimensions (5UD) shows also a very positive feedback (figure 3 and 4) of the user interface concept and the employment of mobile devices in the area of service and maintenance. The continuous high assessment of efficiency, self descriptiveness and learnability allows the conclusion that such applications will be accepted very positive by the end-user. The reason is the provision of all needed information in a mobile portal and the connected reduction of the time-consuming acquisition of information.

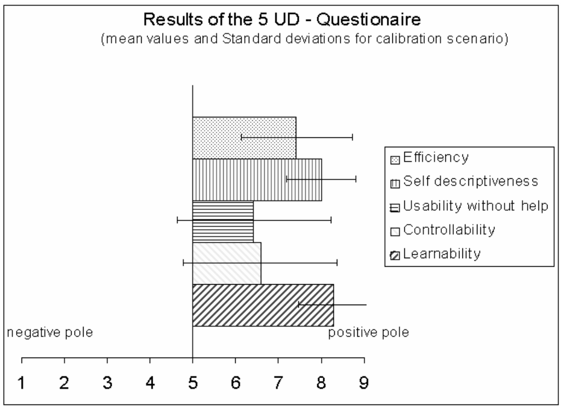

Figure 3: Results of 5 UD – Questionnaire / calibration scenario (Penzkofer, 2002)

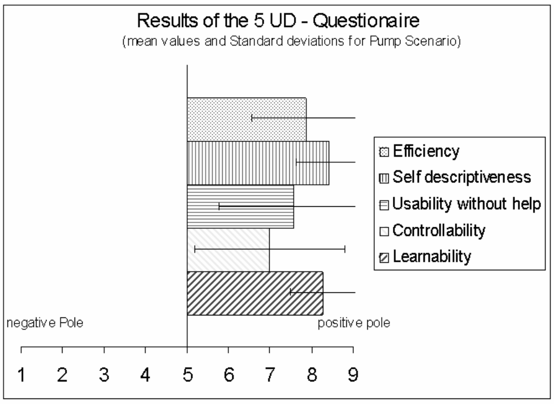

Figure 4: Results of 5 UD – Questionnaire / pump scenario (Penzkofer, 2002)

4. SECOND ITERATION

The results of the first iteration accentuate the need for a second research phase.

4.1 Requirement analysis - Extension to service and maintenance management

In 2003 another analysis focused on the service and maintenance management was performed. The hypothesis was that technician and manager use the same data but they need different views to fulfil their tasks. The analysis was performed in the domains of power generation and petrol production (Table 1).

Table 1 Analysed user groups during the second analysis (service and maintenance management)

Petrol production	Power generation
--	Area management
Area head	Area head
Shift head	--

Usually technician and manager work with the same data. Often they use the same hardware (e.g. there is just one PC for technician and management).
The technician performs inspection of the production system to find elements with malfunctions. Elements with malfunctions are reported to the service and maintenance management.
The service and maintenance manager has to keep the production system in a stable state. Also he has to minimize the economic effort. All reported problems in the production system are discussed in a management meeting regularly (e.g. daily). Every problem will be analyzed under the following viewpoints:

- Safety consequences of the problem: If the problem draws endangering persons with itself, then countermeasures have to be immediately started.
- Probability of downtime: For economic reasons the downtime of the production process must be prevented. If there is a high probability of a downtime the technician has to perform the fault clearance fast without delay.
- Other economic viewpoints like expected lifetime of the process element (exchange or repair the element?), next routine exchange of the element, etc.

Based on these viewpoints a work schedule for the technician is prepared and the technician gets his working order. As expected a result of this analysis was that technician and manager need different views to the information. New requirements to the system are:

- Possibilities for the prioritization of the problems
- Statistical feedback about economics: Number of problems, costs etc.
- Personalized functions: The technicians need other functions and information than the managers.
- Personalized hierarchy of functions.
- History function.

As expected the use of mobile devices was welcomed. The complete list of all requirements is explained in (Butter, 2003). A generalized workflow of the collaboration between the technicians and the management is shown in Wittenberg (2003; see also Butter, 2003).

4.2 User Interface redesign

Based on the results of the second analysis the user interface concept was redesigned. As in the first iteration, a Macromedia Flash ® - based prototype was developed and implemented for use on a mobile web-pad (Figure 5). Figure 6 shows a screenshot of the prototype (view to the documentation).

Figure 5: User interface prototype on a SIEMENS SIMpad ©

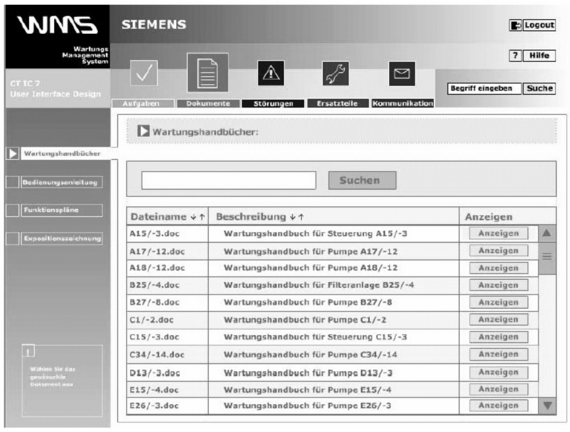

Figure 6: Screenshot of the user interface prototype (Butter, 2003)

4.3 Second evaluation

The second evaluation was performed with four subjects as a usability test. All subjects had experiences as technicians and two subjects also in the field of the service and maintenance management. The subjects had to execute two main scenarios. The first scenario covered the work as a technician. The subjects had to get an overview about their tasks, get information about a pump with disturbances and order spare parts. This scenario addresses open points from the first evaluation. The second scenario focused the management task. The subjects had to prioritize malfunctions of technical elements; they had to send an order to the technician and had to analyze the statistics. After the scenarios the subjects had to fill out an ISONORM-questionnaire (Prümper, 1997). Figure 7 shows the results of this evaluation. The results of the ISONORM-questionnaire are positive.

The two items “Error-tolerance” and “Suitability for individualization” with the low results could not covered by the test scenarios because of the prototype which no related functionality to these items. The complete test design and the results are described in detail in (Butter, 2003).

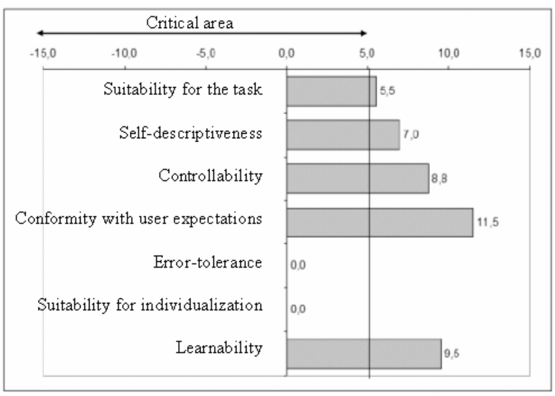

Figure 7: Results of the usability test (Butter, 2003)

5. DISCUSSION

The use of mobile devices in the industrial context of service and maintenance can support the daily work of technicians and managers. The two performed analysis and evaluations shows an acceptance of such systems by the possible end-users.

The user-centred development process based on ISO 13407 gives also a useful guidance designing usable User Interface concepts. User Interfaces developed by this process have a higher quality and attractiveness. Nowadays these factors are required for consumer products but they become more and more important also for non-consumer systems.

But there is still a need for further research. Future points of interest can be the combination of on-site diagnosis with mobile devices and remote-diagnosis. For the management aspects of such systems the integration of ERP systems is necessary.

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